The University of Chicago

# DIGESTIBILITY OF LOBSTERS, SHRIMP AND OYSTERS

A PART OF A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE BIOLOGICAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF HOME ECONOMICS AND HOUSEHOLD ADMINISTRATION

By
SISTER JEANNE D'ARC HURLEY

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# DIGESTIBILITY OF LOBSTERS, SHRIMP, AND OYSTERS[1]

SISTER JEANNE D'ARC

IN VIEW of the fact that there are many ideas and beliefs regarding the digestibility of foods, the paucity of experimental data is surprising. The variety of criteria used in judging whether a food is digestible adds to the confusion. This study was undertaken in order to determine by an *in vitro* method the relative rate and extent of digestion of the protein of certain shell fish and the effects of different methods of cooking upon their digestibility. Lobsters, shrimp and oysters were selected. The cooking methods employed were those which yield well cooked and overcooked products.

A review of other studies concerned with similar problems showed that lobster was the only shell fish included in any study (4). Fish of several types have been experimented upon by the *in vitro* and *in vivo* methods, but the studies have been inadequate. The *in vitro* studies previously reported (4, 6, 16, 19) are practically valueless because the strength of the enzymes was not properly controlled, the enzyme activity was not stopped promptly, or questionable procedures in analysis were used. Neither are the results of the *in vivo* studies (1, 7, 11, 18) of great significance because one, two, or three individuals—usually young and healthy—acted as subjects for periods of only three to six days.

The effect of cooking upon the digestibility of fish has been determined in a few studies (4, 6, 8, 16). In general these studies indicate that cooking decreases the digestibility of fish. The cooking methods were inadequately described, but were probably not such as are used for well cooked products.

## EXPERIMENTAL STUDIES

*Shell Fish Sample.* Fresh shrimp, lobsters and oysters were obtained from a Chicago wholesale market during the spring. Enough of each was prepared at one time to provide samples for the entire series. After cleaning, the whole amount was well mixed. About 300 gms. of the raw product were ground and from this the samples for digestion and drying were taken.

[1] Part of a dissertion submitted to the faculty of the Division of Biological Sciences of the University of Chicago in candidacy for the degree of doctor of philosophy. Received for publication July 5, 1936. The advice, coöperation, and interest of Dr. Evelyn G. Halliday, Dr. Lydia J. Roberts, and other members of the Department of Home Economics and Household Administration are gratefully acknowledged by the author.

*Cooking Methods.* Triplicate samples of 200 gms. of shrimp were placed in 750 cc. of boiling water and cooking continued for 12 minutes. The resulting product was well cooked and tender. To obtain an overcooked product the samples were prepared and cooked in the same manner and the period was continued for 30 minutes. After draining, the samples were ground and placed in covered glass jars in the refrigerator.

Fresh lobsters weighing approximately 2 lbs. each were used. Six of these were cooked by placing each in 3000 cc. of boiling water for 20 minutes. The meat was removed from the shell and that from two lobsters was mixed to make one sample. A portion of this was used for re-cooking. This was placed in a double-boiler and reheated at 92°C. for 10 minutes. This process was used because cooked lobster meat is frequently combined in casserole recipes which are usually cooked in a double-boiler at a temperature below the boiling point of water.

The oysters were washed and drained. Three samples of about 250 gms. each were placed in 500 cc. of water at 92°C., in a double-boiler. The cooking period was 5 minutes. To obtain overcooked products, samples were cooked in a similar way for 25 minutes.

*Digestion Apparatus.* Digestions were carried out in 100 cc. beakers placed in an electric oven containing a specially devised stirring apparatus. This consists of small paddles similar in arrangement to the dasher of an ice cream freezer. The paddles are connected to a bar which is attached to a motor on the exterior of the oven. This device provides a means of thorough mixing of samples and enzyme solutions. The continuous stirring duplicates human digestion as nearly as possible by artificial means.

*Method of Digestion.* Triplicate samples of approximately 10 gms. each were weighed into digestion beakers and placed in the digestion oven. To each sample was added sufficient tenth-normal hydrochloric acid to produce a digestion mixture having a pH of about 2, as shown by the development of a pinkish color due to the presence of thymol blue indicator. At this pH, good activity and stability of the enzyme pepsin were obtained by Northrop (12, 13). Ten cc. of 2 per cent pepsin (Fairchild Brothers', U.S.P.) solution, prepared to develop high activity as shown by McMeekin (10), were poured simultaneously into the beakers. This was accomplished by using graduated cylinders held together in a frame. The time of addition of the pepsin solution was taken as the beginning of the one hour period of digestion.

At the end of the digestion period, a 10 per cent sodium hydroxide solution sufficient to produce a faint pink color in the phenolphthalein

indicator was added. Four cc. of 3 per cent sodium carbonate and 5 cc. of 4 per cent pancreatin (Fairchild Brothers') solution were added together from the graduated cylinders. This gave a final concentration of 0.3 per cent of sodium carbonate, a value found satisfactory by Murlin (2) and Helmer (5), and a pH of about 9 at which Northrop (13, 14) reports good activity and stability of trypsin. This digestion was continued for a short period of 2 hours and a long period of 6 hours. Digestion was stopped by the addition of concentrated sulphuric acid sufficient to bring the pH to 2, with water for diluting.

Digestion mixtures were transferred to graduated centrifuge bottles and centrifuged to remove undigested matter. The clear filtrates were drawn off and analyzed.

*Amino Acid Determination.* Northrop's modification (15) for the Formol titration was adapted for this study. In this adaptation of Sörensen's procedure, small quantities of solution are used and the accuracy of the results is increased by the use of two color standards. The desirability of Northrop's method is indicated by the agreement of results obtained by this method and by Van Slyke's method in Valteich's digestions of casein (20).

*Total Soluble Nitrogen Determination.* The Koch-McMeekin micro-Kjeldahl method (9) was used for the determination of the total soluble nitrogen.

*Total Nitrogen Determination.* The total nitrogen of the food samples was determined by the modification of the Koch-McMeekin micro-Kjeldahl method developed by Chaney and Blunt (3) and a further simplification of procedure adapted for this study. The dried, weighed samples containing approximately 100 mg. of nitrogen and concentrated acid were placed in a 100 cc. Pyrex volumetric flask for the digestion. After completion of the oxidation, the digest was diluted to 100 cc. One cc. of this solution was used for Nesslerization.

*Control Digestions.* The digestion of a casein sample was run parallel to the digestion of each set of triplicate samples in order to check the relative activity of each fresh enzyme solution. The amount of digestion of the casein was determined by means of refractive indices obtained at 22°C., using a Bausch and Lomb immersion refractometer and Robertson's (17) values for the refractive indices of solutions of different amounts of casein in tenth-normal sodium hydroxide and computed change in the index produced by one gram of casein. A preliminary series in which total nitrogen and refractive indices were both determined, indicated that the method is valid.

## RESULTS OF EXPERIMENTS

*Criteria of Digestibility.* The amounts of total and amino nitrogen in soluble compounds during the short period are taken as an indication of the ease of digestion; the amounts for the long period, as an indication of the completeness of digestion.

The values for total soluble nitrogen and for amino nitrogen are shown in this study to be significant indices of digestibility, but these values may not increase proportionally, as the protein breakdown may be brought about so as to increase total soluble nitrogen more rapidly than amino nitrogen and vice versa. The conception of the action of digestive enzymes, as recently discussed and demonstrated by Willstätter and his associates and reported by Waldschmidt-Leitz (21, 22, 23), explains these results. Evidence is presented to show that the breaking up of a protein to molecules of moderate sizes, such as proteoses and peptones, is a reaction independent of subsequent cleavage to still smaller polypeptides and amino acids. It is therefore necessary to consider the amounts and increases in both amino and total nitrogen in order to present a more correct view of *in vitro* digestibility (Table 1).

*Digestibility of Lobster.* Raw lobster appears to have been more rapidly digested than the cooked when judged by the total soluble and amino nitrogen values for the short digestion. Expressed as percentage of total nitrogen, the range, in whole numbers, of soluble nitrogen for the raw is 77 to 79; for the cooked, 52 to 67. The range for amino nitrogen is 30 to 34 for the raw; for the cooked, 18 to 27.

With respect to completeness of digestion, raw and cooked lobster were about equal if judged by soluble nitrogen, since the ranges of values overlap from 68 to 85 per cent. Considering also the amino nitrogen, the raw was slightly more completely digested since 45 to 51 per cent of the nitrogen of raw samples, as compared with 30 to 38 per cent of the nitrogen of cooked samples, was in amino form after the long digestion.

Reheating lobster caused the same change in the ease of digestion as short cooking, but it brought about more complete digestion than the single cooking.

*Digestibility of Shrimp.* Raw, cooked, and overcooked shrimp were practically equal in ease of digestion on the basis of the amounts of soluble nitrogen liberated during the short digestion. Expressed as percentages of total nitrogen, the ranges of values are 52 to 68 per cent for raw and 57 to 68 per cent for cooked and overcooked. The ranges for the amino nitrogen also overlap.

TABLE 1

*Summary of percentages of nitrogen in soluble compounds formed by the action of enzymes upon shell fish**

| PREPARATION AND KIND OF SAMPLES | TOTAL NITROGEN OF SAMPLES | TOTAL SOLUBLE NITROGEN AS PER CENT OF TOTAL N | | AMINO NITROGEN AS PER CENT OF TOTAL N | |
|---|---|---|---|---|---|
| | | Digestion period | | Digestion period | |
| | | Short | Long | Short | Long |
| *Raw:* | | | | | |
| Lobster | | | | | |
| Average | 2.486 | 78.80 | 82.92 | 32.69 | 52.53 |
| Range | | 76.85–79.47 | 80.28–85.57 | 29.93–34.22 | 50.34–55.69 |
| Shrimp | | | | | |
| Average | 2.862 | 59.25 | 89.59 | 26.18 | 38.83 |
| Range | | 51.60–68.66 | 85.17–98.48 | 22.71–30.71 | 36.22–41.90 |
| Oysters | | | | | |
| Average | 0.875 | 63.74 | 82.26 | 38.90 | 43.48 |
| Range | | 60.08–71.06 | 80.09–84.78 | 34.91–45.31 | 39.93–46.79 |
| *Cooked:* | | | | | |
| Lobster | | | | | |
| Average | 2.854 | 61.18 | 75.02 | 22.06 | 32.69 |
| Range | | 52.49–66.56 | 68.13–83.07 | 18.05–27.27 | 29.26–38.45 |
| Shrimp | | | | | |
| Average | 3.874 | 64.00 | 83.64 | 19.67 | 30.47 |
| Range | | 58.28–68.41 | 76.98–90.26 | 17.12–22.54 | 27.42–37.95 |
| Oysters | | | | | |
| Average | 1.807 | 76.23 | 97.68 | 21.75 | 31.86 |
| Range | | 70.46–83.41 | 88.22–102.40 | 18.09–27.78 | 22.94–38.64 |
| *Reheated:* | | | | | |
| Lobster | | | | | |
| Average | 2.812 | 63.96 | 82.67 | 21.58 | 32.11 |
| Range | | 60.81–66.86 | 79.00–87.22 | 16.82–25.74 | 29.34–37.59 |
| *Overcooked:* | | | | | |
| Shrimp | | | | | |
| Average | 3.644 | 61.58 | 83.07 | 20.66 | 31.78 |
| Range | | 57.35–68.41 | 75.25–90.95 | 17.59–26.75 | 27.99–35.21 |
| Oysters | | | | | |
| Average | 1.892 | 85.47 | 91.76 | 25.78 | 29.65 |
| Range | | 77.27–94.75 | 86.88–98.97 | 20.71–30.96 | 26.42–34.19 |

* Averages and ranges represent triplicate determinations on triplicate samples, *i.e.*, 9 analyses for raw samples and 27 analyses for cooked and overcooked samples of each type of shell fish.

The shrimp products were all completely and about equally digested to soluble forms during the long period, judged by both the soluble and amino nitrogen values. The ranges of the percentages of soluble nitrogen are 85 to 98 for raw and 75 to 90 for cooked and overcooked; of amino nitrogen, 36 to 42 for the raw and 27 to 38 per cent for the cooked and overcooked.

Cooking for a short or long period, therefore, did not impair or improve the digestibility of shrimp.

*Digestibility of Oysters.* Cooking appeared to improve the ease of digestion of oysters if judged by the soluble nitrogen liberated during the short digestion. Expressed as percentage of total nitrogen, the ranges, in round numbers, are from 70 to 83 and 77 to 95 for the well cooked and overcooked samples, while the corresponding values for raw are 60 to 71 per cent. But the cooked samples were less easily digested if judged by the amino nitrogen, so there is some inconsistency in the results of this series.

Cooking also improved the completeness of digestion in terms of the soluble nitrogen values. From 88 to 100 per cent of the total nitrogen of these samples is in soluble compounds after the long digestion, as compared with the 80 to 85 per cent of the raw. The amino nitrogen values are not significantly higher for the long than for the short period and consequently they do not contribute information about the completeness of digestion.

Overcooking had no effect on the ease or completeness of digestion of the oysters. This was surprising in view of the fact that the overcooked samples were tough and hard, whereas the short-cooked ones were soft and tender.

*Comparative Digestibility of Shell Fish.* The values for the raw fish are contradictory, since lobster ranks first with respect to soluble nitrogen while oysters lead with respect to amino nitrogen. If the values for the raw are disregarded, however, it may be quite definitely concluded from this study that in the cooked state oysters are more quickly and more completely changed to soluble compounds than are either of the others, but all three are about equal with respect to the rapidity and completeness with which they liberate amino nitrogen.

REFERENCES

(1) Atwater, W. O.: Über die Ausnutzung des Fischfleisches im Darmkanale im Vergleich mit der des Rindfleisches, Ztschr. f. Biol. 24: 16, 1888.

(2) Carman, J. S., Smith, H. G., Havens, G. C., and Murlin, J. R.: The nutritive value of cereal breakfast foods. II. Digestibility in vitro, with a study of methods, J. Nutrition, 6: 91, 1929.

(3) Chaney, M., and Blunt, K.: The effect of orange juice on the calcium, phosphorus, magnesium, and nitrogen retention and urinary organic acids of growing children, J. Biol. Chem., 66: 829, 1925.

(4) Chittenden, R. H., and Cummins, G. W.: On the relative digestibility of fish flesh in gastric juice, Am. Chem. J., 6: 318, 1884.

(5) Helmer, O. M.: A study of trypsin and its activation by enterokinase, Unpublished doctor's thesis, University of Chicago, 1927.

(6) Hinard, G.: Le Poisson der mer. Quelques observations sur sa composition chimique et ses proprietes alimentaires, Bull. Soc. d'Hygiene, 11: 550, 1923.

(7) Holmes, A. D.: Experiments on the digestibility of fish, U. S. Dept. Agric. Bull. 649: 14, 1918.

(8) Honigsberg, P. Von: Untersuchengen über die Verdaulichkeit des Fleisches, Wien. med. Blatter, 5: 582, 614, 1882.

(9) Koch, F. C., and McMeekin, T. L.: A new and direct nesslerization micro-Kjeldahl method and a modification of the Nessler-Folin reagent for ammonia, J. Am. Chem. Soc., 66: 2066, 1924.

(10) McMeekin, T. L.: Studies on the purification of pepsin, Unpublished doctor's thesis, University of Chicago, 1925.

(11) Milner, R. D.: Experiments on the digestibility of fish and poultry, Conn. Pub. Documents, (1903), 34, 17th Ann. Report Storrs Agric. Exper. Sta., 34, 1906.

(12) Northrop, J. H.: The combination of enzyme and substrate. I. A method for the quantitative determination of pepsin. II. The effect of the hydrogen ion concentration, J. Gen. Physiol., 2: 113, 1919–1920.

(13) Northrop, J. H.: The influence of the hydrogen ion concentration on the inactivation of pepsin solutions, J. Gen. Physiol., 2: 465, 1919–1920.

(14) Northrop, J. H.: The inactivation of trypsin. III. Spontaneous inactivation, J. Gen. Physiol., 4: 261, 1921–1922.

(15) Northrop, J. H.: A convenient method for the formol titration, J. Gen. Physiol., 9: 263, 1925–1926.

(16) Popoff, M.: Über Verdauung von Rind un Fischfleisch bei verschiedenen Art der Zubreitung, Ztschr. f. physiol. Chem., 14: 524, 1890.

(17) Robertson, T. B.: Note on the refractivity of the products of the hydrolysis of casein, and a rapid method of determining the relative activity of trypsin solutions, J. Biol. Chem., 12: 23, 1921.

(18) Rosenfeld, G.: Der Nahrungswert des Fischfleisches, Zentralbl. f. inn. Med., Leipzig, 27: (1906), 169.

(19) Splittgerber, A.: Chemische Zusmmensetzung und Nahrwert des Fischfleisches, Inaugural-Dissertation der Westfalischen Wilhelmsuniversitat zu Münster, 1901.

(20) Vahlteich, H. W.: A study of the action of trypsin on casein, J. Biol. Chem., 82: 737, 1929.

(21) Waldschmidt-Leitz, E.: Enzyme actions and properties. Translated by Robert Walton, New York: John Wiley and Sons, Inc., 1929.

(22) Waldschmidt-Leitz, E., Balls, A. K., and Waldschmidt-Grasor, J.: Über Dipeptidase und Polypeptidase aus Darm-Schleimhaut. XVI. Mittelung zur Spezifität tierischer Proteasen, Berichte, 62: 956, 1929.

(23) Waldschmidt-Leitz, E., and Purr, A.: Über Proteinase und Carboxy-Polypeptidase aus Pankreas. XVII. Mitteilung zur Spezifität tierischer Proteasen, Berichte, 62: 2217, 1929.